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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

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The Adaptability of Petroleum Oils

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Hydraulic Power Transmission

The Adaptability of Petroleum Oils

THE idea of applying the principles of hydraulics to power transmission dates back to the seventeenth century investigations of Pascal, and may be said to be based upon the law which he formulated to the effect that,

> "The pressure applied to a liquid at any point is transmitted equally in all directions, or the pressure in a liquid not acted upon by external forces is equal at all points."

It was not until the latter part of the eighteenth century, however, that actual application of the principles evolved by Pascal was made to industrial machinery in the form of the hydraulic press. The nineteenth century saw considerable activity in the extension of this idea. Notable among the developments was the piping of London for hydraulic power and the discovery that use of an accumulator would enable one to overcome the low speed limitation of the more simple form of power transmission device. From then on the hydraulic accumulator played an important part in this work, even though it was accompanied by costly maintenance of throttle valves.

Throughout all this development of hydraulic machinery water was used as the power transmitting medium. Outstanding among the more familiar applications have been the hydraulic elevator and the accumulator which is employed in steel mill service for operation of the horizontal sliding covers over soaking pits wherein steel ingots are reheated to bring them to an even temperature.

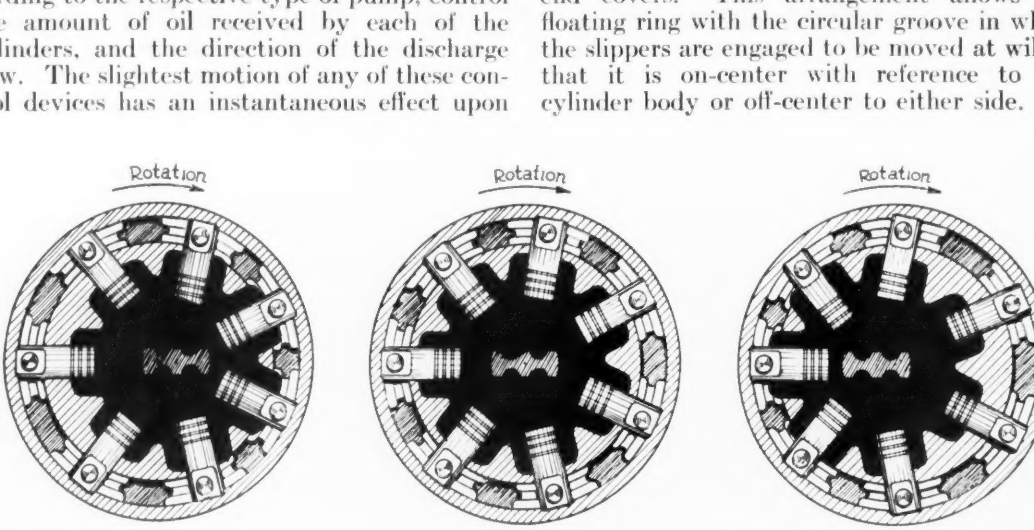
The accumulator was not adaptable to transmission of power at accurately controlled variable speeds. The necessity for this in operation of naval ordnance therefore led to development of a special type of transmission involving a suitable pump and a companion fluid motor whose speed was dependent upon the amount of fluid delivered to it by the pump. Petroleum Oil was adopted for such systems. So successful did it prove that today straight mineral oils of varying viscosity, according to operating pressures and the duty to be performed, are used almost entirely in such service.

PRINCIPLES OF OPERATION

In contrast with the accumulator which is generally restricted to transmission of power in a straight line direction through reciprocating motion, the rotary type pump, with its accompanying rotary hydraulic motor, converts electric or mechanical power as delivered by a constant speed electric motor or other prime mover operating in one direction, into hydraulic power of variable speed, capable of most accurate control.

Furthermore, it is practicable to reverse the direction in which this power is delivered, irrespective of the direction of operation of the driving motor. This is accomplished by means of a floating ring, tilting box or control pendulum device, which, by their adjustment ac-

cording to the respective type of pump, control the amount of oil received by each of the cylinders, and the direction of the discharge flow. The slightest motion of any of these control devices has an instantaneous effect upon end covers. This arrangement allows the floating ring with the circular groove in which the slippers are engaged to be moved at will so that it is on-center with reference to the cylinder body or off-center to either side.



Courtesy of American Fluid Motors Company.

Figs. 1, 2 and 3—Diagrammatic view showing operation of the Hele-Shaw pump and relative location of the floating ring at different stages of operation.

the driving shaft, which operates the hydraulic motor, the speed and direction of rotation being contingent upon the position of the control.

The Hele-Shaw Transmission

The working parts of this device and their relations to one another are as follows:

A rotor made up of radial cylinders, the number and size of which vary with the capacity of the pump, is mounted on bearings seated in the covers of the pump. Fastened to one end of the cylinder body and extending out through the cover of the pump is the spindle by means of which it is rotated by the prime mover.

Fixed in the opposite cover and extending into the cylinder body from the other end is a shaft with two ports running through it parallel to its axis. This shaft does not rotate. The two ports open into small chambers on either side of the shaft between the shaft and the cylinder body. Each chamber is in communication with the cylinders that happen to be on that side of the shaft at the moment. It is through these ports that the fluid is drawn into the pump and discharged from it, the shaft serving as a central cylindrical valve.

In each radial cylinder is a plunger with a gudgeon pin fastened to its outer end. This pin engages in slippers or rollers, one on each side of the plunger.

These slippers or rollers set in circular grooves, one in each half of a floating ring which encircles the cylinder body. This floating ring is mounted on ball bearings seated in a guide block on each end and the ring and guide block assembly is supported on guides on the two

It is this arrangement that gives stroke to the pump and control of the amount of stroke and the volume and direction of discharge.

The hydraulic motor end of the transmission converts hydraulic pressure into rotary motion; its working parts are identical with the pump. As oil under pressure flows from the pump through the two outside flanges, it passes into the central valve through the ports and into the radial cylinders that register with them. The pressure of the oil drives the plungers and these cylinders outward and forces the rollers against the floating ring so as to impart a rotary motion to the cylinder body and the driving spindle.

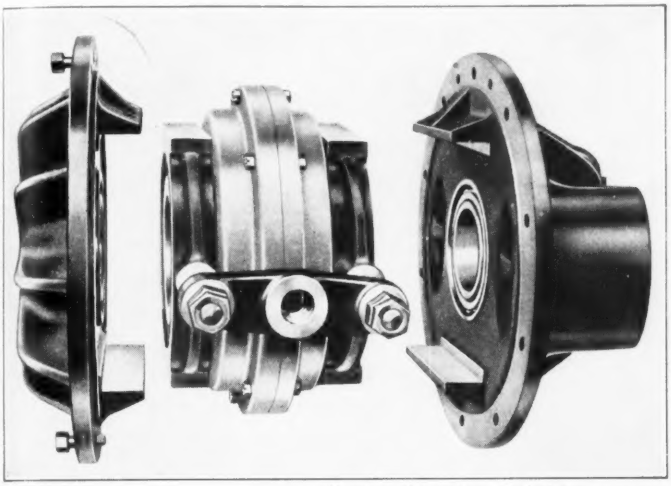
As the cylinder body rotates successive cylinders are brought opposite the high pressure ports and the cylinders which have passed these ports are carried around the central valve until they communicate with the discharge port on the low pressure side of the system.

As the cylinders come opposite the discharge port, the fluid is expelled from the motor and continued rotation brings the cylinders in communication with the other entry port and the cycle is repeated, each plunger making two strokes for each rotation of the cylinder body.

The speed of the motor end varies directly with the volume of oil delivered to it by the pump, and, as the pump discharge can be controlled at all times by adjusting the position of the floating ring to regulate the stroke of the pistons, it is obvious that no adjustments of the motor are required for varying speeds.

The torque of the motor depends upon the pressure of the fluid. Whatever the load may be on the motor, the pressure automatically

builds up and the speed is reduced until the torque is sufficient to overcome it, or until a predetermined limit is reached, at which the pressure in the system shifts the floating ring of the pump almost to neutral position,



Courtesy of American Fluid Motors Company.
Fig. 4—Floating ring assembly and pump covers showing the guide block supports on the covers of the Hele-Shaw pump.

cutting off the delivery from the latter, except for the amount necessary to maintain the pressure against leakage.

The operation is as follows.

1. When the floating ring is off-center to the left of the cylinder body. This condition is illustrated in Figure 1. It should be remembered in studying this diagram that the cylinder body is being rotated by the prime mover in the direction indicated continuously and at a constant speed about the fixed shaft containing the ports and that it carries the plungers and slippers or rollers, around with it. It is then clearly seen how, during the upper half of each revolution the plungers are forced inward by the slippers, or rollers, following the races in the floating ring, producing the discharge stroke of the pump, while during the lower half they are drawn outward producing the suction stroke.

2. When the floating ring is on-center with the cylinder body. When this condition exists, as illustrated by Figure 2 the position of the plungers in the radial cylinders remains unchanged during the revolution and, although the pump is running, the plungers have no stroke and the fluid remains motionless.

3. When the floating ring is off-center to the right of the cylinder body. This condition is shown in Figure 3. This diagram shows how the direction of discharge is reversed without changing the speed or direction of rotation of the cylinder body. Now the plungers are forced inward and have their discharge stroke during the lower half of the revolution and are drawn out and have their suction stroke during the upper half.

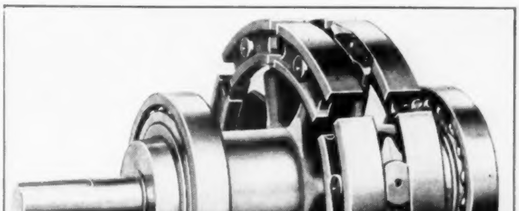
It can readily be seen that the distance the floating ring is eccentric with respect to the cylinder body determines the amount of the stroke and, hence, the volume of the discharge and that the finest variation from zero to the maximum can be obtained.

The floating ring can be shifted so rapidly that the discharge of the pump can be reversed from the maximum in one direction to the maximum in the opposite direction in less than one second.

The bearings on which the floating ring is mounted permit it to rotate freely and the ring is carried around with the slippers or cylinders. Due to the fact that the ring and the cylinders are rotating about different centers (except when the pump is in the neutral position) there is a slight motion of the slippers with reference to the ring and to one another as the distance between the slippers increases at one side of their path and diminishes at the other. Oil that leaks past the plungers is held in the races of the floating ring by centrifugal force and keeps them lubricated. Excess oil is drained from the cover to a reservoir in the bedplate.

The Northern Pump

The Northern high-pressure hydraulic pump is of the radial piston type, having a nitralloy pintle supported on both ends so that the pintle at all times is concentric with the bore



Courtesy of American Fluid Motors Company.
Fig. 5—Cylinder body assembly of the Hele-Shaw pump, showing plungers, slippers, ball bearings and spindle.

of the rotating cylinder block. By this construction, the leakage at high pressure is reduced to an absolute minimum because no plain bearing is involved and it is not necessary

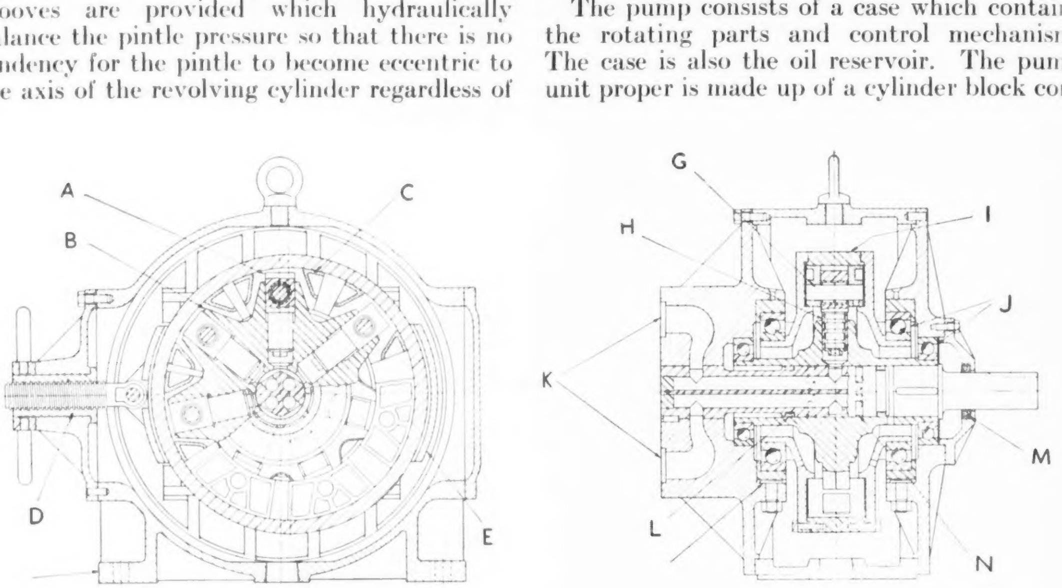
to provide clearance for an oil film. Pressure grooves are provided which hydraulically balance the pintle pressure so that there is no tendency for the pintle to become eccentric to the axis of the revolving cylinder regardless of pump pressure. The revolving cylinder block is a one piece nitralloy forging rotating on two large ball or roller bearings.

The cross heads are flat surfaces provided with oil grooves. This nitralloy surface is lubricated by oil from the piston sleeves.

The pistons are made with a square section where they rub on the cross head and are supplied with long sleeves which are fitted with sufficient radial clearance so that no pressure or wear on the cross head can be transmitted from the piston to the piston sleeve and any wear from the piston sleeve to the cylinder bore is thereby eliminated. Both piston and piston sleeve are nitralloy.

The piston pin is hardened and ground and needle bearings are supplied to take the oscillating load by the piston and the piston pin. The piston pin is supported on both sides by a one piece bronze shoe called a slipper. This slipper operates a short distance in proportion to the piston movement. Sufficient mass is provided in the bronze shoe so that centrifugal force will hold it outward against the steel ring under all conditions of operation, except starting.

A hardened and ground steel ring is provided so that the bronze slippers operate against a polished, hardened steel surface. The piston area is small in proportion to the area of the slippers, so that only a small unit pressure on the slippers is experienced even at maximum pump pressures.



Courtesy of Northern Pump Company.

Fig. 6—Sectional views of the Northern rotary radial piston pump. A indicates crosshead, B nitralloy cylinder block, C the bronze oscillating shoe, D the stroke adjustment, E the rotor guide connection, G the hardened crosshead pin which rocks on the rollers, H the nitralloy piston sleeves, I the rotor, J ball bearings, K the intake and outlet, L roller bearings which insure concentricity, maximum clearance and minimum leakage. M the oil seal which is under no pressure, and N the nitralloy timing shaft.

The Oilgear Pump

The pump consists of a case which contains the rotating parts and control mechanism. The case is also the oil reservoir. The pump unit proper is made up of a cylinder block containing five or more radial cylinders and a rotating driving member carrying the pistons in its rim.

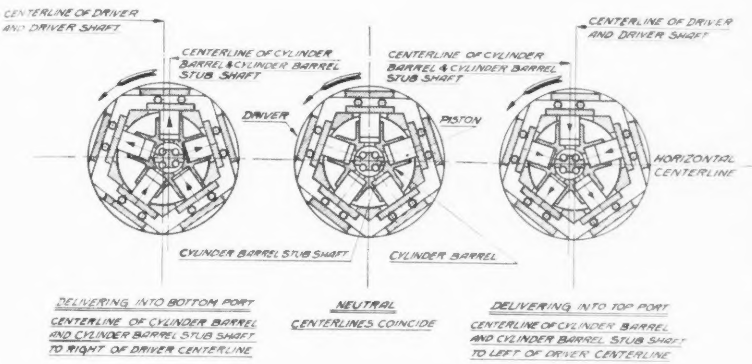
The cylinder block is carried on a non-rotating, hardened and ground ported pintle fitted in a movable arm or pendulum. The driving member is carried on a rotary shaft in a fixed position mounted in roller or ball bearings.

The pistons are fitted in radial bores in the cylinders and driven through tee shaped crossheads which are the connecting links between the driving member and cylinder block. The piston reactions are transmitted from these crossheads which are attached to the pistons, through rollers to reaction plates on the driving member. By swinging the arm or pendulum, the revolving cylinder may be shifted relative to the driver which actuates the pistons. Both driver and cylinder barrel continuously revolve around centers which coincide when the swinging arm is in central position.

As the cylinder is moved to the right or left the length of the piston stroke is correspondingly increased resulting in a flow of oil through the pump in direct ratio to the length of the stroke. This mechanism also gives a reversal of flow, oil passing through the pump in one direction when the swinging arm is moved to the right, and in the other direction when it is moved to the left of center.

In operation, with the cylinder block rotating on a common center with that of the

driver, no oil is pumped. If the cylinder shaft is moved slightly off-center, only a small amount of oil is pumped. If the cylinder shaft is moved a greater distance off-center, a proportionately greater amount of oil is pumped.



Courtesy of The Oilgear Company.

Fig. 7—Schematic diagram of the Oilgear variable delivery pump, showing relative location of the rotating parts at various stages of operation.

The position and movement of the cylinder shaft can be controlled very accurately, so that the discharge of the pump can be varied smoothly over a stepless range from zero to maximum. The pump is protected against overload by a relief valve which can be adjusted to operate at any pressure within the working capacity of the pump.

The flow of oil is pulsationless and imparts extremely smooth action to the motor which it drives.

All rotating parts are carried on ball bearings. Piston thrust is taken on roller bearings. As all moving parts are thoroughly lubricated under high pressure, wear is practically eliminated.

This transmission system consists of a volumetric variable displacement pump, driving either one or a series of constant or variable displacement motors and using high grade lubricating oil as the power fluid which flows from unit to unit through pipe lines; thus permitting the installation of the pump at a point quite distant from the motors which it drives and also simplifying the installation by eliminating the shafting, gears, etc., required for mechanical power transmissions. In several instances the system extends over two or more floors.

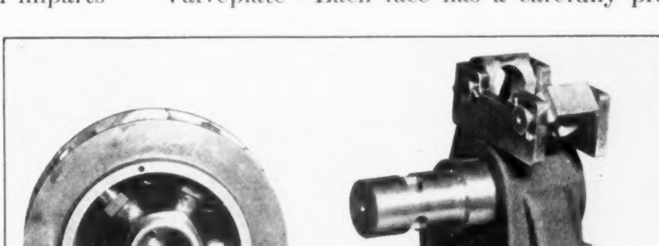
The Waterbury Transmission

The transmission consists essentially of two units, a pump commonly called the A-End, and a motor called the B-End. On a casual inspection the two units appear to be quite similar except that the pump is fitted with a control shaft whereby the operator is enabled to vary the piston stroke of the pump, and thereby the amount of oil delivered. The B-End or motor has a constant stroke and its speed is governed therefore by the oil delivered to it. Other detail differences appear, but each unit has a similar rotating group, consisting of main shaft, cylinder barrel, socket ring, pistons, connecting rods and connected parts.

Parts of Transmission

Cases—All the working parts are enclosed within the case castings, the open or large end of which is bolted by long case bolts to the valveplate. The outer end of the case carries a bushing for the main shaft and a stuffing box to make the shaft oil tight. The case is filled with oil to lubricate the moving parts and to make up any leakage from the oil used to transmit the power. This power oil is confined to the cylinders and valveplate passage, and the case itself is not under pressure.

Valveplate—Each face has a carefully prepared surface against which the cylinder barrel rotates, and carries two semi-annular passages called ports, which receive the discharge oil from the cylinders. As the cylinder barrel rotates, the cylinder barrel ports pass in suc-

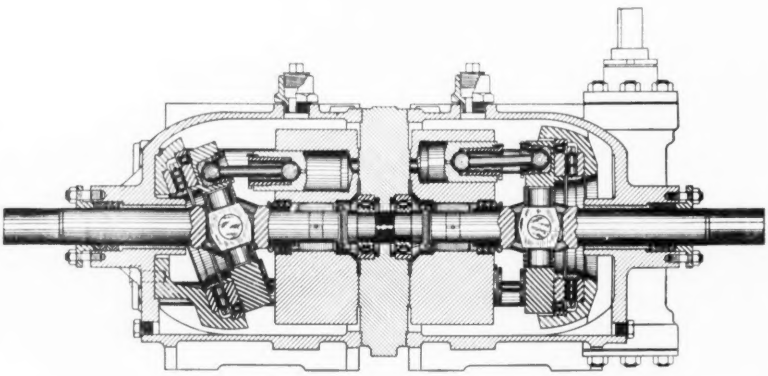


Courtesy of The Oilgear Company.

Fig. 8—Showing at the left the cylinder block, pistons and driver on the Oilgear pump. In this illustration the center line of cylinder rotation is to the right of the center line of the driver and piston rotation. Note the progressive stroke positions of the pistons. The figure to the right shows the control pendulum, cylinder shaft with oil ports to cylinders, and rocker shaft.

cession over the valveplate ports, thus providing one port to receive oil and the other to discharge oil to the cylinder.

Each valveplate is provided with two relief valves. These relief valves also have in them small ball check valves, called replenishing valves, which will admit make-up oil from the case to the low pressure side if needed. Oil flows through these replenishing valves to fill the pressure system when first starting up and to provide make-up oil in operation.



Courtesy of The Waterbury Tool Company.

Fig. 9—Section through a type C Waterbury transmission where pump and motor are combined. B-end is shown at the left, with A-end on the right.

The valveplate also carries the outer roll race for the bearing supporting the main shaft.

Tilting Box and Angle Box—The purpose of the tilting box is to carry a thrust roller bearing against which the socket ring may rotate at the desired angle to the shaft. The tilting box is suspended, and may be oscillated, on two trunnions formed on the box and which bear in bronze bushed seats in the case. The output of the pump and speed of B-End are governed by the angle of the tilting box. Projecting from the back of the box is a pin on which the trunnion block of the control shaft operates.

The angle box performs a similar function to that of the tilting box, but is set to carry the socket ring at a fixed angle to the main shaft. It is not adjustable in the machine.

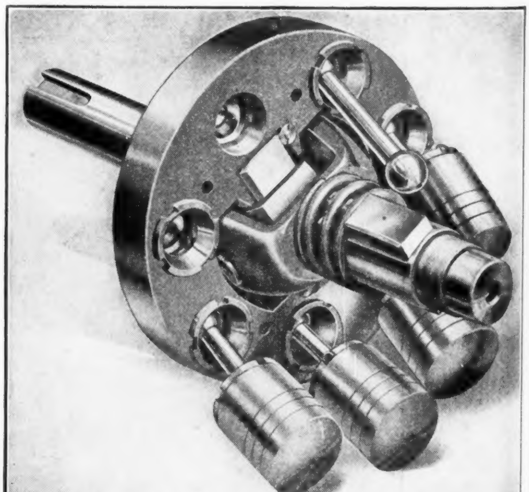
Control Shaft Group—The control shaft tilts the tilting box on its trunnions in either direction from the perpendicular and this governs direction and speed of B-End. It consists of a threaded nut, a control shaft or screw and suitable bearings. The threaded nut is held by its flange or collar between two thrust rings, one resting on the case and the other held by the control nut bearing.

The threaded part of the control nut operates the screw which is held from rotating by a spline and which carries a trunnion block in a housing on its lower end. This trunnion block can rotate in the housing and slide on the pin attached to the tilting box.

As the control nut is turned the control shaft is moved up or down, carrying with it the trunnion block, thereby changing the angle of the tilting box.

In addition to the rotary type of control described, a sliding control is built and furnished when desired. In this type of control the nut and threaded shaft are replaced by a sliding shaft, and movement of the tilting box is produced by pulling up or pushing down the control shaft.

Main Shaft—The A- and B-Shafts are alike. The shaft rotates in a bushing in the case and in a roller bearing in the valveplate. Its inner end bears against the intershaft disc to locate it endwise and should have a reasonable play. At the socket ring it is formed into a closed yoke to form part of the universal joint with the socket ring. The shaft carries the cylinder barrel and rotates it by two barrel keys fitting in holes in the shaft.



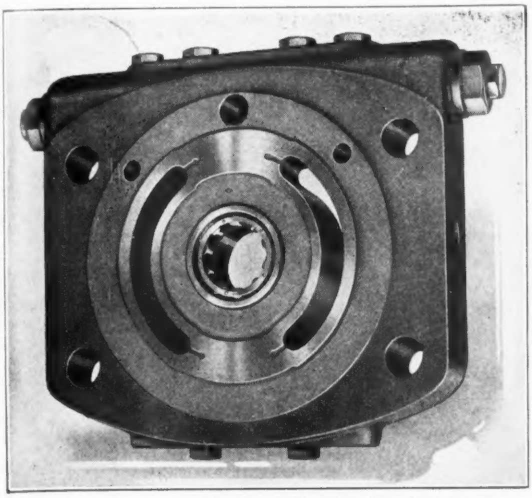
Courtesy of The Waterbury Tool Company.

Fig. 10—Showing the socket ring and main shaft group of the Waterbury transmission.

A barrel nut is threaded on, and its only function is to prevent the barrel slipping off

when rotating parts are removed from or assembled in the case.

Cylinder Barrel—The cylinder barrel contains seven or more nicely ground cylinders and is keyed to the shaft by the barrel keys. A barrel spring between the back of the barrel and a collar on the shaft holds the barrel against the valveplate when not under pressure. When in operation the cylinder barrel is held against the valveplate by the pressure on the difference in areas between the cylinder and port. These are proportioned so that the pressure at no time becomes excessive. The cylinder barrel bearing against the valveplate is lubricated by oil forced from the pressure ports and this surface under load takes on a high polish and will last practically indefinitely. The cylinder barrels and keys do not transmit the working torque.



Courtesy of The Waterbury Tool Company.

Fig. 11—Valve plate of the Waterbury transmission.

Pistons—The pistons are ground to a good working fit in ground cylinder bores and no packing is used. Properly fitted, the leakage is extremely small, being about one-half of one per cent of maximum displacement from all causes under normal conditions.

Connecting Rods—Each piston is connected to the socket ring by a connecting rod having spherical ends and drilled throughout its length to admit oil from the high pressure system to the two end bearings. The two ends of the connecting rod are held by split end bushings and threaded cap nuts.

Socket Ring—The socket ring is provided with seven or more bronze sockets to receive the connecting rods. On the back the socket ring has one race of a roller bearing, which transmits the thrust of the pistons.

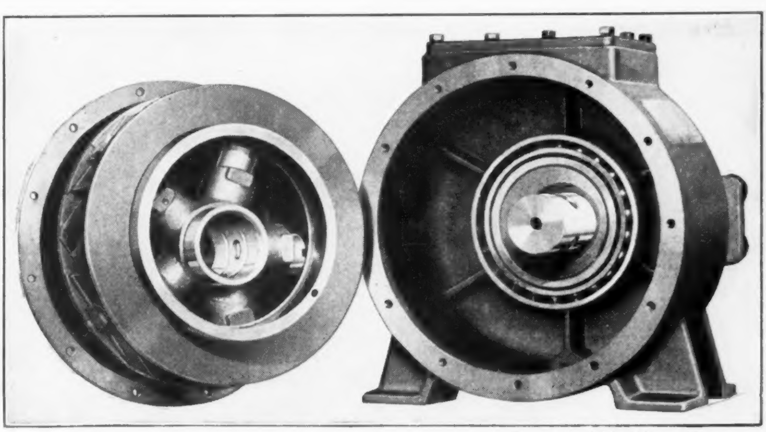
The body of the socket ring has inward projections, forming pockets for the main shaft trunnion bearing blocks which are secured by taper pins.

Universal Joint—The shaft and socket ring are connected by a universal joint, consisting of a shaft trunnioned block. This rotates through a limited angle in the bearing block in the socket ring and carries a pin which rotates in a bushing in the main shaft, making a form of Hooke joint.

The working torque of the gear is transmitted through the socket ring, universal joint and main shaft.

Elimination of Clutch

In certain types of operation use of hydraulic means of power transmission is instrumental in eliminating the necessity for friction clutches and frequently belt or gear connections. In paper mill service maintenance, repair and lubrication of such elements may often amount to a considerable sum. Any means of reducing this expense without impairing overall plant or machine efficiency is, therefore, advantageous, especially if provisions for speed control can be rendered automatic and capable of instantaneous adjustment.



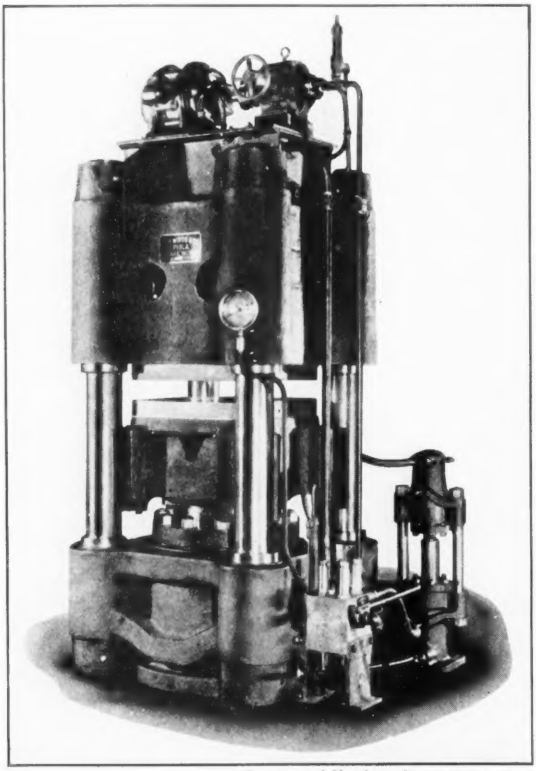
Courtesy of The Oilgear Company.

Fig. 12—Exploded view of the Type RQ-5 Oilgear motor. This unit is made up of a rotating cylinder block with 5 or more radial cylinders and closely fitted pistons, a driven rotating member carrying the pistons in its rim and a non-rotating hardened and ground ported pintle, which carries the cylinder block The driven member and output drive piston are mounted in ball or roller bearings.

PUMP AND MOTOR LUBRICATION

A certain amount of leakage of oil is allowed for in construction of the modern hydraulic pump and motor in order to provide for com-

plete lubrication. According to the design, this leakage takes place between the face of the cylinder barrel and face of the valveplate, or past the plungers or packless pistons and valve to be held in the races of the floating ring by



Courtesy of Northern Pump Company.

Fig. 13—Installation of a Northern pump on a combination die sinking and vulcanizing 1000 ton press. Note location of pumping element on the top of the press and accessibility of all transmission piping.

centrifugal force. Inasmuch as the oil is under considerable pressure, whenever the mechanisms are functioning, there is positive assurance of a sufficient film of oil between all working surfaces of the pistons, plungers, cylinder barrel and valve unit (according to some authorities), provided the oil temperature is not allowed to rise to an extreme.

Leakage of oil or working fluid of course results in a certain reduction in effective displacement of the pump, which can be noted at the motor end by the effect on speed or revolutions. Obviously it will affect the ultimate efficiency of the entire transmission. This will not be noticeable unless the unit is employed in power transmission service where very accurate speed control is of importance, as for example in the paper industry.

There is no loss of oil, however, even though there is leakage within the pump and motor mechanisms, for that oil which serves to lubricate is drained from the pump and motor cases into a suitable reservoir located in the bedplate of the unit or elsewhere according to the location of the transmission. In the operation of paper mill machinery where the pumps are often located apart from the fluid motors and connected to same by suitable piping systems, the leakage oil is drained from the cases into a common oil reservoir in the basement. From here it is transmitted to a filter or purifier. The cleansed oil is then pumped back to the suction side of the transmission pumping system.

Indications of Impaired Lubrication

Faulty lubrication due to too thin an oil will be indicated by inability to develop and hold the desired pressure, overheating of the pump, or reduction in power output. Lack of sufficient oil in the system will be indicated by the pump plungers being unable to make their full length of stroke.

Freedom from Air Essential

An hydraulic power transmission system functions at its best when entirely filled with oil and as free as possible from air. For this reason, filling of the system requires considerable care and attention. Those who are familiar with the instructions issued by motor car builders relative to use of hydraulic fluid in hydraulic brakes, know full well of the benefits to be derived from following these instructions closely.

Air will most usually gain entry at the time of filling the transmission with oil, unless there may be leakage at some high point in the system, or between the tank and pump. Normally, however, any aperture capable of leaking air will also allow oil to pass out, especially when the pump is operating at full stroke. Entry of air may also be caused by leaky packing, restriction of the pump intake, which may be caused by sludge accumulations or location of this inlet above the surface of the oil in the tank. The latter may frequently occur if the oil is being rapidly circulated through the system.

Entry of air at the time of filling cannot be prevented entirely. It can, however, be materially reduced by adding make-up oil very slowly and where practicable straining through one or two thicknesses of cheesecloth. Subsequent formation of air pockets can be eliminated by locating suitable air relief valves at certain of the high points in the pipe connections as well as at the top of the expansion tank. After filling with oil, if the pump is run for a certain length of time, any entrained air will gradually work its way out of the oil in circulation and into the base of the pump housing from whence it will rise to the expan-

sion tank after the pump is shut down. Removal of such air can also be accelerated by locating a baffle plate in the oil tank. This will develop a certain amount of surging and facilitate rise of air bubbles. Lighter oils can be more easily freed from air than heavier products. It is important to bear this in mind when first running the pump after filling with oil, the time of running being gauged according to the viscosity of the oil. Normally this must be determined by experience.

The expansion tank also serves as a reservoir to insure that there is sufficient oil in the system, the level of the latter serving as an indication as to when refilling may be necessary.

Considerable care must also be observed to prevent entry of abrasive foreign matter at the time of filling the transmission. One must realize that the contact surfaces of the working elements of both pump and fluid motors are machined to a high degree of accuracy. Presence of abrasives in the oil supply, or acids, which may have been used in pickling of piping or connections, may easily lead to scoring or pitting of the pressure surfaces, or ruination of the accuracy of the ball or roller bearings.

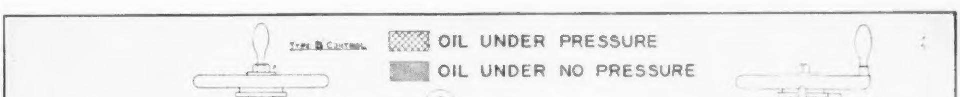
Adequate cleaning of all piping and accessory parts at the time of assembly will assure against presence of pickling acids. Later, when filling with oil, if a highly refined straight mineral oil is used, with due care in handling, the possibility of entry of abrasive foreign matter or formation of sludge should be reduced to a minimum.

and steel. To this end, provision is made where necessary for adequately cooling the oil after it has passed through the pump and motor, before it is returned to the former. Recommended practice is to regulate the cooling system so as to reduce the oil temperature to at least 110 degrees Fahr.

Some types of systems will develop less heat than others. The volumetric type of pump frequently has the advantage in this regard. Obviously minimum heat generation within the system is advantageous in that more constant viscosity of the oil will be maintained with more positive assurance of effective lubrication. Reduction in heat developed also precludes abnormal vaporization in certain types of oil. This is of distinct advantage in that possibility of carbon formation is also reduced.

Cooling can be accomplished by water or air. Until recently the former has been most prevalent, cooling coils being installed in the oil reservoir or supply tank, with suitable water connections. Latest developments, as applied to installations where the electric motor is virtually an integral part of the pump, provide for location of oil piping surrounded by cooling fins at the outboard end of the electric motor. A fan attached to the rotor adjacent to these coils passes a current of fresh air constantly over the cooling element to reduce the temperature of the oil, unless the room temperature is abnormally high.

Discussion of the detrimental results which may accrue from pumping hot oil will be of interest. Obviously, there will be a reduction in the viscosity or body of the oil, dependent upon the temperature. Along with this reduction in viscosity, the pressure-resisting ability of the oil film will be decreased. Considering



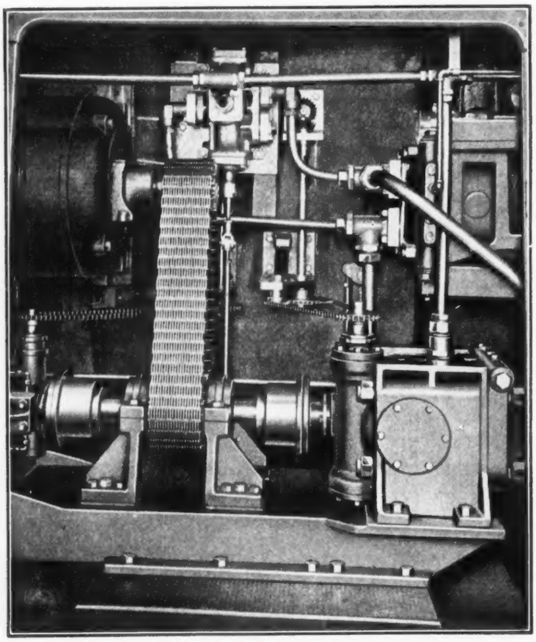
Courtesy of American Fluid Motors Company.

Fig. 14—View of the Hele-Shaw transmission adapted to air cooling by a fan driven from the outboard end of the electric motor. Oil under pressure is indicated by crosshatching. Oil level and piping for oil under no pressure to and from the cooling element and to the pump is shown in gray.

Oil Cooling

The temperature of the oil as returned to the pump must never be allowed to become too high, due to the very serious effect which it may have upon lubrication, especially where this latter must be maintained between bronze

that at certain stages of the stroke of any such pump there will be severe thrust pressures developed, it is evident that an overheated oil film may become so weakened as to be incapable of actually preventing metal-to-metal



Courtesy of The Waterbury Tool Company.
Fig. 15—Showing the manner in which a Waterbury drive can be compactly built into a machine housing.

contact. Where this occurs between bronze and steel, the latter may develop a wiping effect, the bronze being virtually melted or burned onto the opposing steel surface. This will necessitate considerable expensive overhaul and parts replacement.

In connection with oil cooling, careful consideration must be given to the arrangement and tightness of the water cooling system, due to the detrimental effect which water leakage may have on lubrication. This is one of the chief reasons for recommendation of the use of oils of very high degree of refinement. Presence of any appreciable amount of water may lead to formation of emulsions with certain types of oil. In a closed system, such as an hydraulic power transmission system, where there is normally but little opportunity for the oil to rest and separate itself from water emulsions, oxidation may develop with subsequent sludge formation. All this will be aggravated under the higher temperatures which are developed during pumping and circulation.

Sludge is a distinct detriment to lubrication, for it will tend to accumulate in clearance spaces, ports or other small apertures in the pump, to interfere with free flow and leakage of the oil past those parts which require a lubricating film. Sludge accumulations in some oils may also be conducive to acidity, which may lead to corrosion of ball or roller bearing elements and other highly polished parts.

OIL CHARACTERISTICS

Manufacturers of hydraulic pumping machinery are agreed that only lubricating oils of a very high degree of refinement should be used. It is especially important that they be entirely free from abrasive or contaminating foreign matter. High demulsibility, ro an ability to separate readily from water, is not always essential, however, unless the system may be subjected to considerable water leakage. On the other hand, low oxidizing and carbon-residue forming tendencies are most important characteristics. They will normally be indicative of the durability of the oil and a guide to its resistance to breakdown.

Viscosity, in turn, is of importance as an indication of body or relative fluidity. According to the make of pump, manufacturers' recommendations will range from 140 to 1200 seconds Saybolt at 100 degrees Fahr. High pumping pressures and operating temperatures will call for heavier oils, the range depending

Courtesy of Northern Pump Company
Fig. 16—Showing a Northern radial piston pump direct connected to an electric motor. This unit is equipped with a Type Y hand lever control. This pump is used in connection with hydraulic operation of an electric furnace.

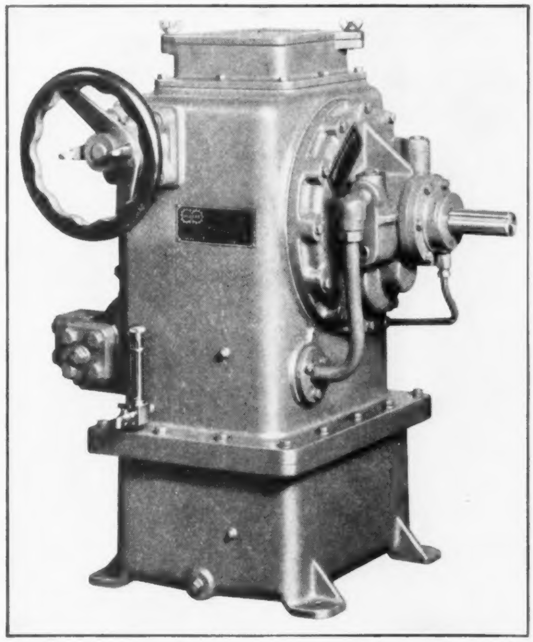
upon the type of system, the extent to which pipe lines may be restricted, and the necessity for keeping down pipe line head loss. Oilgear advises the adoption of 45 degrees Fahr. as the dividing line between the use of light and medium oil, according to their specifications, which suggest a viscosity of 140 seconds Saybolt at 100 degrees Fahr. for the light grade, and 320 seconds Saybolt for medium oils. The builders of the Hele-Shaw pump, in turn, prefer an oil of approximately 1000 seconds Saybolt at 100 degrees Fahr. for normal pressure operations. The Waterbury hydraulic system requires an oil of medium viscosity, i.e., in the neighborhood of 320 seconds Saybolt at 100 degrees Fahr. Northern, in turn, has adopted a range in regard to viscosity dependent upon peak pump pressures and duty cycle which directly affects the temperature of the oil. This range will generally run from 500 to 1200 seconds Saybolt at 100 degrees Fahr.

By reason of the obvious necessity for an oil of high refinement, consideration of those tests which will be indicative of this will be of interest. These tests will include demulsibility, neutralization and carbon residue content. Viscosity, in turn, as already mentioned is indicative of the body and the pressure and temperature resisting ability, while the pour test may become a factor in cold climate operation.

Emulsification and Demulsibility

There is a distinct relation between emulsification, or the rate at which an emulsion will develop when an oil is circulated or agitated in the presence of water, and demulsibility, or the rate at which this emulsion will subsequently precipitate itself or settle out. In actual operation of an hydraulic power transmission system, possibility of emulsification in the presence of water will require consideration wherever design may allow the latter to gain entry. The extent to which it may become detrimental can be predicted by laboratory study of the demulsibility of the oil being used; normally it will depend upon the degree of refinement. For the more specific information of the operator, this means the extent to which the oil is a straight-run product or pure distillate, the care used in fractionating or segregation of distillates within a narrow range of viscosity, and the extent to which the finished products are subsequently filtered or otherwise refined.

With certain types of heavier or more viscous oils, emulsified matter will settle out more slowly than from fluid products, or those of lower viscosity. This will be especially true where the same conditions of refinement have prevailed. The emulsifying tendency of certain oils will also be affected by oxidation. As a result, in a system which is not entirely free from air, continued circulation of oil in the presence of water at temperatures much above 150 degrees Fahr., may lead to more or less



Courtesy of The Oilgear Company.

Fig. 17—Showing an external view of an Oilgear volumetric pump of the multiple plunger variable displacement type. Note control element and oil piping.

oxidation, which will materially increase the emulsifying and sludge forming tendencies of the oil. Inasmuch as these phenomena are so directly tied up with air, water, and temperature, one can readily appreciate why builders of hydraulic pumps and motors are so concerned about installing means to free their systems of air, reduce temperatures and design their water cooling coils in such a manner as to prevent leakage as much as possible.

Acidity

The value of the Neutralization Number of an oil at any period of service, as an indication of corrosive acidity, is an open matter. Extensive tests have shown that in some oils high organic acidity has apparently no serious effect upon their lubricating ability; other oils, in turn, only seem to require a slight increase in acidity to develop a very objectionable sludge forming tendency. One must conclude, therefore, that it is a question more of the type of organic acidity rather than the actual amount which should be considered. In this regard, it is interesting to mention that authorities of the petroleum industry are giving this much study.

The American Society for Testing Materials* has discussed acidity under the subject "Neutralization," in a decidedly helpful manner. Their thoughts are very interesting, viz.:

"Practically all petroleum lubricating oils contain substances, of varied and indeterminate chemical composition, which have acid characteristics. The proportion of these substances present in an oil is commonly referred to as its 'organic acidity.' These acid compounds are, mainly, natural constituents of crude petroleum and their presence in finished lubricating oil is not necessarily an indication of improper refining or poor quality.

"A large proportion of the petroleum lubricating oils now produced undergo treatment with mineral acid and caustic alkali in the course of refining. If the refining operations are not properly conducted, small quantities of one or the other of these chemicals may remain in the finished oil and, of course, are undesirable and unnecessary impurities.

"The 'Neutralization Number' of an oil is defined as the weight in milligrams of potassium hydroxide required to neutralize one gram of oil. It represents the sum of the quantities of mineral and so-called organic acids present in the oil, or the difference between the organic acidity and the alkali present in the oil. If, as is usually the case, no mineral acid or alkali is present in the oil, the neutralization number is directly proportional to 'organic acidity'."

Significance of Results:

"It is obvious that the effect of alkali or mineral acid in a petroleum oil is deleterious, and it is usual to specify that the Alkali or Mineral Acid Neutralization Number shall be either zero or some extremely low figure. The practical significance of 'organic acidity' is complicated by many considerations. The essential facts are as follows:

1. Oils derived from certain crude oils commonly show low neutralization numbers while oils from other crude oils show relatively high neutralization numbers, unless subjected to special processes.
2. The organic acids normally present in lubricating oil are not corrosive and have no directly harmful effects.
3. It is contended by some, although the supporting evidence is not absolutely definite, that the presence of organic acids improves the friction-reducing qualities of oil."

Bearing these facts in mind, obviously one need not worry as to the acid content of a new oil, provided it has been carefully refined and properly neutralized, nor should the Neutralization Number be taken as a criterion of initial quality. After some oils have been in service, on the other hand, they may show marked rise in Neutralization Number, over the initial specification, as indicated by test on the used oil according to the method of test adopted by the A.S.T.M. This should be taken as an indication that change of oil may be advisable.

* The Significance of Tests of Petroleum Products—Report of Committee D-2 of the A.S.T.M., July, 1929—P. 42-43.

Carbon Residue

The test for carbon residue is of interest due to the degree to which it may be indicative of subsequent difficulties on account of carbon accumulations. This test was originally developed for the purpose of comparing the carbon-forming tendencies of various lubricating oils for internal combustion engine service. It has since been proved of value in connection with many other types of operation where temperatures may be reached which approximate the initial vaporization point of certain components of the oils being used. Its value in connection with hydraulic power transmission equipment subjected to heavy duty and high pressures, which would tend to develop heat within the system, is, therefore, obvious, as an indication of the extent to which possible accumulation of residues in ports or small apertures might occur.

To appreciate the meaning of the "carbon residue" test, one must realize that petroleum lubricants are mixtures of a variety of hydrocarbon compounds which may differ widely in their physical and chemical properties. Some of these may vaporize even at atmospheric pressure and at comparatively low temperatures, leaving more or less of a non-volatile residue. Close fractionation and accurately controlled distillation will remove certain of these compounds in the course of refinement. Any free carbon which may be present in very finely divided state in the semi-finished oil can later be almost entirely removed by judicious filtration. The final product, if refined according to accepted practice in the handling of high grade lubricants, should show a very low carbon residue by either the Conradson or Ramsbottom Method of Test.*

CONCLUSION

With this brief analysis of the advantages of builders and operators of hydraulic power transmission systems having a more thorough understanding of the part played by the petroleum industry in refining high grade oils to meet their requirements, it is hoped that a more sympathetic interest in the problems of all concerned will be fostered.

* See Lubrication, September, 1933, P. 105-8.

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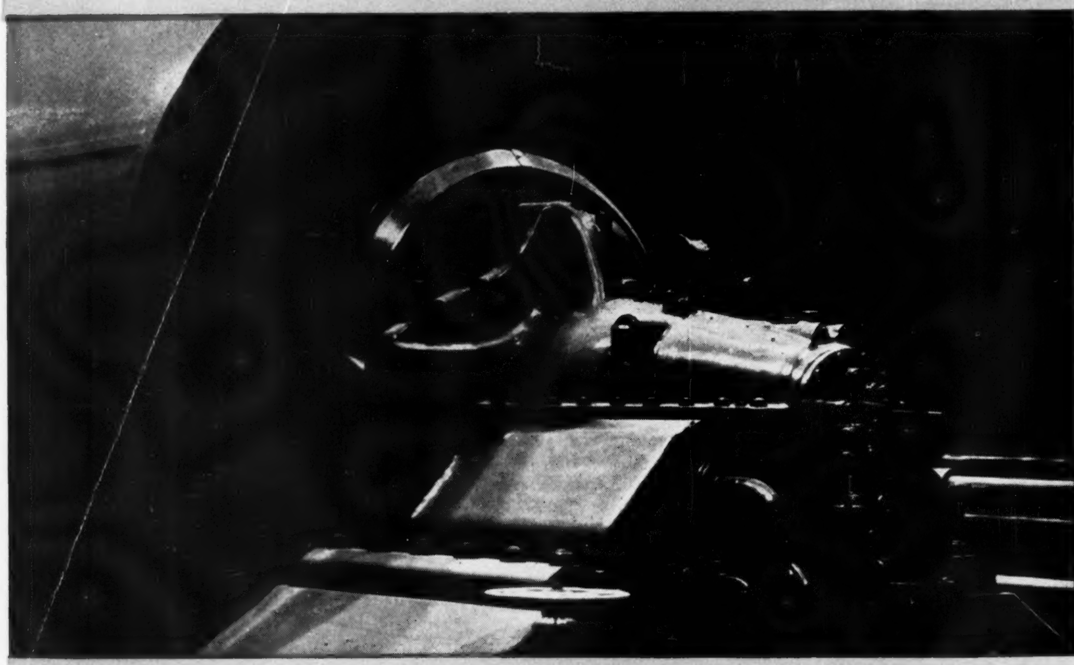

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